1994
Executive Research Project
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The Pentagon: An Intelligent Renovation?

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The Industrial College of the Armed Forces
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Fort McNair, Washington, D.C. 20319-6000

19941201 066

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT Distribution Statement A: Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NDU-ICAF-94-A7	5. MONITORING ORGANIZATION REPORT NUMBER(S) Same
6a. NAME OF PERFORMING ORGANIZATION Industrial College of the Armed Forces 6b. OFFICE SYMBOL (If applicable) ICAF-FAP	7a. NAME OF MONITORING ORGANIZATION National Defense University
6c. ADDRESS (City, State, and ZIP Code) Fort Lesley J. McNair Washington, D.C. 20319-6000	7b. ADDRESS (City, State, and ZIP Code) Fort Lesley J. McNair Washington, D.C. 20319-6000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
The Pentagon: An Intelligent Renovation?

12. PERSONAL AUTHOR(S) FREDRICK R. Budd

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Research	FROM Aug 93 TO Apr 94	April 1994	52

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

SEE ATTACHED

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Judy Clark	22b. TELEPHONE (Include Area Code) (202) 475-1889 22c. OFFICE SYMBOL ICAF-FAP

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

DTIC QUALITY INSPECTED 1

ABSTRACT

Maintenance of the Pentagon has been neglected during its 50 year life, and it has numerous structural, mechanical, electrical, plumbing and information management and telecommunications deficiencies. In 1989, the Congress approved a Department of Defense initiative to completely renovate the Pentagon over a period of approximately twelve years. The renovation provides the Department of Defense an opportunity to modernize its headquarters into an efficient, cost effective, and flexible building structure which will facilitate change, and above all, be responsive to its users.

In recent years, technology has significantly reduced the cost of automated building systems (e.g., heating, ventilating, air conditioning, lighting, fire, life safety, security) and information management and telecommunications systems. It has contributed to the realization of two important goals: increasing the productivity of the orgnaizations within a building and reducing building life cycle costs. The "intelligent building" concept as espoused by the Intelligent buildings Institute (IBI) of Washington D.C. and documented in the Army's <u>Functional Description for Intelligent Buildings</u>, capitalizes on these new technologies and emphasizes importance of building life-cycle costs. This concept also advocates designing buildings to accommodate long-term technological change. It also encompasses the growing emphasis on creating a work environment to enhance worker performance, understanding, communications, overall productivity, and mental and physical health. The trend is to consider the building as a significant tool in the accomplishment of tasks rather than merely a structure to house personnel and equipment.

With technology and competition driving costs of automated buildings down, initial costs of Intelligent (automated) Buildings are within 4.5% of "traditional" building costs. Real examples have shown that the life-cycle savings associated with Intelligent Buildings are often paid back within a few years through operational and increased productivity savings.

The Intelligent Building concept is one that, if carefully managed, will reap long-term life cycle cost savings and provide business and government productivity gains which can assist in maintaining a competitive edge in today's global economy. The Pentagon Renovation is one of the largest projects of its kind in the world. It provides an opportunity to provide long-term benifits for the 25,000 plus employees that work there as well as saving the taxpayer dollars by implementing integrated building systems that will reduce building life-cyle costs.

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DTIC TAB ☐

Unannounced ☐

Justification

By

Distribution /

Availability Codes

Dist	Avail and/or Special
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ABSTRACT

Maintenance of the Pentagon has been neglected during its 50 year life, and it has numerous structural, mechanical, electrical, plumbing and information management and telecommunications deficiencies. In 1989, the Congress approved a Department of Defense initiative to completely renovate the Pentagon over a period of approximately twelve years. The renovation provides the Department of Defense an opportunity to modernize its headquarters into an efficient, cost effective, and flexible building structure which will facilitate change, and above all, be responsive to its users.

In recent years, technology has significantly reduced the cost of automated building systems (e.g., heating, ventilating, air conditioning, lighting, fire, life safety, security) and information management and telecommunications systems. It has contributed to the realization of two important goals: increasing the productivity of the orgnaizations within a building and reducing building life cycle costs. The "intelligent building" concept as espoused by the Intelligent buildings Institute (IBI) of Washington D.C. and documented in the Army's Functional Description for Intelligent Buildings, capitalizes on these new technologies and emphasizes importance of building life-cycle costs. This concept also advocates designing buildings to accommodate long-term technological change. It also encompasses the growing emphasis on creating a work environment to enhance worker performance, understanding, communications, overall productivity, and mental and physical health. The trend is to consider the building as a significant tool in the accomplishment of tasks rather than merely a structure to house personnel and equipment.

With technology and competition driving costs of automated buildings down, initial costs of Intelligent (automated) Buildings are within 4.5% of "traditional" building costs. Real examples have shown that the life-cycle savings associated with Intelligent Buildings are often paid back within a few years through operational and increased productivity savings.

The Intelligent Building concept is one that, if carefully managed, will reap long-term life cycle cost savings and provide business and government productivity gains which can assist in maintaining a competitive edge in today's global economy. The Pentagon Renovation is one of the largest projects of its kind in the world. It provides an opportunity to provide long-term benifits for the 25,000 plus employees that work there as well as saving the taxpayer dollars by implementing integrated building systems that will reduce building life-cyle costs.

BACKGROUND

Introduction

This paper will discuss how "Intelligent Building" concepts can be used during the Pentagon Renovation Program to reduce building life-cycle costs while increasing overall user/occupant productivity. It will begin with an historical perspective on the Pentagon and an overview of the Pentagon Renovation Program. It will then introduce the Intelligent Building concept in some detail with real world examples. Intelligent Building principles will then be applied to the renovation with particular emphasis on life-cycle costs. Specific conclusions and recommendations related to the Pentagon Renovation will be provided at the closing.

Overview of Renovation.

In 1989, the Congress approved a Department of Defense initiative to completely renovate the Pentagon over a period of approximately twelve years with construction costs estimated at $1.4 billion and Information Management and Telecommunications (IM&T) costs estimated at $890 million. According to a recent status report to Congress, the renovation program is broken up into seven separate projects which overlap each other throughout the renovation. The first is the replacement of the Heating and Refrigeration Plant, which is located adjacent to the Pentagon and is currently under construction. The second is the renovation of the basement and mezzanine areas currently in the design phase. The remaining

projects, all above ground, divide the Pentagon into five separate phases or "wedges".* The intent is to completely gut sections of the building in a phased approach (moving people out and then back in) until the renovation is complete. The end result will be a completely new building on the inside and a facelift on the outside.

It appears to be just another building renovation — hire some architects to design an aesthetically pleasing building (traditionally what they do best), and then award some construction contracts to build to the architect's drawings. Sounds like the classical process — right? Yes, but maybe it's time for ***change***. In recent years, ***automation*** of building systems has picked up momentum and has contributed to the realization of two important goals: increasing the productivity of the organizations within a building and reducing building life cycle costs. A new process has evolved over the last ten years that has proven to be effective in achieving these goals by integrating multidiciplinary engineering functions early in the design phase of a new or renovated building. This is a process which, if executed properly on the Pentagon Renovation, would yield productivity benefits for the tenants and savings of taxpayer dollars over the life of the building. Before examining this new process or way to approach the design of the renovated Pentagon, it's important to get acquainted with the building's history.

Historical Perspective

* Office of the Secretary of Defense. March 1, 1994. Status Report to the Congress on Renovation of the Pentagon. Washington DC. pp. 20-21

According to the status report to Congress*, the Pentagon was constructed from September 1941 to January 1943 for the purpose of consolidating the War department under a single roof to facilitate and increase the efficiency of running the complex bureaucracy required to manage the execution of World War II. The building recently celebrated its fiftieth anniversary as the headquarters for the Department of Defense (DOD). It houses the staffs for the military Services and a number of DOD agencies, including approximately 25,000 military and civilian workers; it measures 6,500,000 square feet, with 3,800,000 occupiable, and has the largest ground area of any office building in the world. The Pentagon has also been designated a National Historical Landmark by the Secretary of the Interior.

> The status report to Congress** also reveals that the building has suffered from decades of neglect and under-funded maintenance and repair programs. Many of the building systems have deteriorated beyond economical repair and require complete replacement. Building code violations and unsafe conditions are rampant, which have been brought about by the Pentagon's non-compliance with the fire protection and life safety standard established over the last 50 years.

Daily power failures have required separate emergency power and uninterrupted power supplies to be installed where they normally would not have been needed.

Discussions with technical experts in the Pentagon Renovation Office indicate that the information management and telecommunications physical infrastructure is literally "jammed" in many locations and cannot easily accommodate the frequent

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* Ibid, pp. 1

** Ibid, pp. 6

technology changes required by the military Services and DOD agencies. In addition, over the years each military Service and DOD agency has implemented its own separate video, data, and voice networks throughout the Pentagon. There has been no configuration management of the IM&T infrastructure for the building. Consequently, there have been duplication and interoperability problems between and within the military Services and DOD agencies. To put it bluntly: ***the building is in bad shape.***

INTELLIGENT BUILDINGS

A Different Look at Building Systems

Traditionally, new or renovated buildings were designed primarily to provide environmentally controlled space. Factors related to ***aesthetics*** and the ***up-front*** *costs* were the most important considerations during the design phase. However, corporate global competitiveness, the driving forces to increase worker productivity, and new emerging technologies automating many building systems have directed owners and tenant users attention to ***life-cycle*** *cost* of occupancy and the building's capability to support an organization's ***mission***. Focus has shifted to evaluating how the building can increase worker productivity and how it will support overall organizational cost-effectiveness.

Life-cycle building costs and increased organizational productivity are important elements in a building's design and management that must be thoroughly evaluated during the course of the Pentagon Renovation Program. This government program must be responsive to the taxpayers by being cost-effective over the life cycle of the building. The "intelligent building" concept, as espoused by the Intelligent Buildings Institute (IBI) of Washington D.C.[1], emphasizes the importance of building life cycle-costs and advocates designing a building to accommodate long-term technological

change. The IBI defines an intelligent building as*:

> one which provides a productive and cost-effective environment through optimization of its four basic elements — structure, systems, services and management — and the interrelationships between them. Intelligent buildings help building owners, property managers, and occupants realize their goals in the areas of cost, comfort, convenience, safety, long-term flexibility, and marketability.

The IBI goes on to say that: "There is no intelligence threshold past which a building 'passes' or 'fails.' Optimal building intelligence is the matching of solutions to ***occupant needs***."

Meeting the occupant's needs should be reflected in the performance criteria for any building. In an effort to understand this concept better, the U.S. Army Information Systems Engineering Command (ISEC) recently published a draft Functional Description for Intelligent Buildings** that lists the following key user objectives:

- o Provide a comfortable office environment by integrating intelligent management systems, building automation, information systems, and facility management systems, maximizing satisfaction and convenience for people working in the building.
- o Increase office productivity and creativity.
- o Integrate a wide range of services and systems into a unified whole.

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* Intelligent Buildings Institute. (1987). Intelligent Building Definition. Washington DC. pp. 8.

** Systems Engineering Directorate, U.S. Army Information Systems Engineering Command. (January 19, 1993). Functional Description Intelligent Administrative Building. pp.3.

o Equip buildings to accommodate unforeseen future changes as well as add, change, and rearrange the various facilities' systems with minimal or no disruption of service.

o Serve as a center to receive and transmit information and support management efficiency.

o Provide building services and tenant interaction with these services, and

o Minimize the facility ***life cycle cost***.

It is important to understand the needs of the occupants — the ***ultimate customers.*** The Pentagon is the headquarters for the United States military. The Department of Defense military and civilian occupants of the building are in a continuous state of change. These changes can be classified into three categories: (1) **technology insertion** — related to continuous upgrades to telecommunication, administrative, and command, control and intelligence systems (2) **organization** — related to the many frequent moves and reorganizations by the military Services and DOD agencies within the building, and (3) **personnel** — related to the frequent rotation of the military employees. The intelligent building concept, if used early in the design of the Pentagon Renovation, could go a long way in accommodating these changes in a cost-effective and efficient operation over the life cycle of the building.

In recent years, there has been a growing emphasis on creating a work environment using the latest technologies to enhance worker speed, understanding, communications, overall productivity, and mental and physical health. The trend is to

consider the building as a significant tool in the accomplishment of tasks rather than just a structure to house personnel and equipment. The intelligent building concept encompasses these trends and promotes a ***participatory team approach*** with user involvement early in the design process to reduce life cycle costs and provide productivity gains. However, before discussing the reasons why the intelligent building concept should be used for the Pentagon Renovation, it is important to understand the basic characteristics of an intelligent building.

Intelligent Building Characteristics

There are a number of characteristics that define varying degrees of "intelligence" in an intelligent building. However, there is one salient feature of all intelligent buildings — its structure is designed to accommodate change in a "convenient, cost-effective manner".* It is not necessary for an intelligent building to have the latest systems and equipment, but it must be able to accommodate them when needed.

The Intelligent Building Definition** specifies four elements and associated characteristics of intelligent buildings that support the owner and occupant needs:

1) **Building Structure** is made up of "structural components, various architectural features and interior finishes and furnishings." Intelligent buildings have the following desirable attributes:

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* Intelligent Buildings Institute. (1987). Intelligent Building Definition. Washington DC. pp. 6.

** Ibid.

o energy-efficiency

o effective use of daylight (especially in those areas where video display units are used)

o raised floors for controlled Heating, Ventilating and Air Conditioning (HVAC) to each workspace to allow for easy changes to underfloor wiring

o space for cables in risers, wiring closets and plenums

o interior finishes that account for acoustical effects, lighting quality, static electricity and ergonomic considerations

o architectural solutions that recognize the evolutionary needs of the owner, developer, tenant and end-user with respect to technological functionality are the most intelligent*

2) **Building systems** provide a hospitable environment for users and equipments — major ones include HVAC, lighting, life safety, and electric power (additional ones from the IBI definition are shown in figure 1); these energy-consuming systems can be monitored and controlled through the use of microprocessor-based computer devices and networks

3) **Building services** traditionally include security guards, information desks, in-building parking, office cleaning and ***tenant services***. Tenant services have increased over the years and require additional explanation. Central air conditioning became a tenant service when it replaced window units. The use of centrally managed utilities in shopping centers became ***a tenant service*** when the owner

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* Ibid.

HEATING, VENTILATING AND AIR CONDITIONING
- Multiple Zones
- Multiple Fan Systems
- Multiple Chillers, Pumps and Cooling Towers for Single Failure Operation
- Multiple Furnaces/Boilers
- Free Cooling Winter Cycle
- Heat Pumps
- Heat Recovery
- Thermal Storage
- Variable Air Volume
- Variable Speed Pumping

LIGHTING
- Switching
- Dimming
- Scheduling
- Zone Control
- Central Control
- Tenant Lighting Usage Report
- Occupancy Sensing
- Signage
- Telephone Access

ELECTRICAL POWER
- Power Distribution and Access
- Busway
- Transfer Switching Arrangement
- Fault Indication
- Ground Fault Protection
- Emergency Power Bus
- UPS Bus
- Tenant Submetering
- Load Management
- Emergency Generators

WIRING DISTRIBUTION
- Integrated Power, Lighting, Electronic & Control Wiring
- Flexible Wiring Systems
- Underfloor Duct
- Cellular Duct
- Poke-Thru
- Surface Mounted System
- Power Pole
- Undercarpet Wiring

COMMUNICATIONS
- Cabling
- Antenna
- Local Area Networks
- Private Branch Exchange and Services
- Messaging Systems (Voice and Video)
- Off-premise Communications
- Services and Interfaces
- Closed Circuit Television
- Teleconferencing

CONTROLS
- Centralized Multiplex
- Distributed Control
- Direct Digital Control for Fan Systems and Chillers
- Redundant Control Air Compressors
- Direct Digital Control Network
- Tenant BTU Metering (Normal Consumption, After Hour)
- Direct Digital Control for Variable Air Volume (VAV) Terminals
- Adaptive Direct Digital Control
- Battery Backup for Direct Digital Control
- Chiller Efficiency Monitoring
- Energy Monitoring
- Low Leakage Outside Air Dampers
- Energy Management
- Air Quality Monitoring & Control

ACCESS CONTROL
- Time of Day Control
- Zoned by Tenant
- Parking Access Control
- Elevator Control
- Access Records Management

SECURITY
- Communications Link
- Guard Station
- Perimeter Intrusion
- Time Controlled Secure Access

LIFE SAFETY
- Centralized Multiplex w/Test and Reset
- Fire Dept. Connection
- Alarm Verification
- Voice Output
- Fire/Smoke Spreading Control

ELEVATORS AND ESCALATORS
- Dynamic Load Balancing
- Demand-Limiting
- Emergency Controls
- Life Safety Interface

DOMESTIC HOT WATER HEATING
- Modular Hot Water Equipment
- Heat Pump Water Heaters
- Heat Recovery
- Booster Heaters

INFORMATION MANAGEMENT
- CPUs
- Word Processing
- Personal Computers
- Fax Machines
- Photocopying Machines

Figure / Intelligent Building System Characteristics

realized it was more economical to provide such services ***centrally*** than for each tenant to provide them for himself"*. More recent tenant services that have been associated with the intelligent building are landlord-provided voice, video, and data communications services to building occupants. Several points on landlord-provided communications require emphasis:

- o "***Centralized communications*** services permit the integration of demand across the multiple organizations residing within a single facility, and in turn it permits the capturing of economie of scale inhardware, operating costs, technical support, and transmission"**. Operating costs would be less and taxpayers would benefit.

- o ***Centralized communications*** "services requires the management of a complex, multi-vendor system"***; it is more cost-effective and simpler for an end user to specify requirements to a centrally managed organization which interfaces with service providers than for each user to set up individual organizations to perform this function.

- o "***Centralized communication*** services represent a significant

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* Ibid.

** Ibid. p. 8.

*** Ibid.

approach to extending the useful life of a multi-tenant structure"*; lack of centralized management within the Pentagon has resulted in uncoordinated use of precious riser and communications closet space and greatly reduces the ability to expand current capabilities; "Tenants share a common space within the building, and it is in their long term interests that the space is economically utilized and well managed. Centralized management of communications systems goes a long way towards that end"**.

(4) **Building Management** functions have historically "included leasing management, property management, maintenance management, and management of building services. Modern buildings also include energy, security, fire, communications, information systems, and related cable management"***; building managers are increasingly relying on integrated automated computer based systems to manage these myriad functional responsibilities; future goals for building management include a "***lights out***" operation where the building ***manages itself*** with minimal human intervention.

Intelligent building characteristics are also defined in the ISEC draft Functional

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* Ibid.

** Ibid. p. 10.

*** Ibid.

Description for Intelligent Buildings*. It divides the intelligent building into four "functional subsystems": ***facilities***, ***building automation***, ***information*** and ***integrated management***. Although this breakout into subsystems is different than the IBI definition, these definitions are consistent and complement each other.**

The above definition, elements and characteristics provide some insight in what makes up an "intelligent" building. Whether or not the intelligent building concept should be applied to a project like the Pentagon Renovation depends one important factor: ***building life cycle-costs***. The ***reduction in costs*** of a business operation has always been a fundamental goal of our free-market system. In the past decade, the global market place has created an environment where companies around the world have had to reduce operational costs and increase productivity in order to retain a competitive edge. So, how does an intelligent building reduce life-cycle costs? In order to answer this question, we must examine how intelligent buildings affect productivity and operational cost savings.

Intelligent Building — Productivity Savings

A key factor in reducing costs in government and commercial businesses over the building life cycle is improvement in productivity. The question becomes, do intelligent buildings improve productivity? If so, how much? In his article Intelligent

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* Systems Engineering Directorate, U.S. Army Information Systems Engineering Command. (January 19, 1993). Functional Description Intelligent Administrative Building. pp.14.

** It is not the intent of this paper to compare the two documents other than to say that they complement each other.

Design Passes IQ Test*, Paul E. Beck, Editor in Chief, Consulting-Specifying Engineer, cites the West Bend Mutual Insurance Company as an example where productivity increased significantly when the company moved (in 1991) to a new location and incorporated intelligent systems into the design of the new 149,000-sq-ft headquarters building in Milwaukee, Wisconsin. It should be pointed out that it is relatively easy to claim a product or process improves productivity, it is quite another to prove it. However, in this case researchers at the Center for Architectural Research and the Center of Services Research and Education at Rensselaer, Troy, New York, developed a methodology to ***measure increases in productivity*** due to the new West Bend facility. They measured productivity for twenty-six weeks prior to moving into the new facility, and for twenty-four weeks after the move was completed. In addition, the productivity during the transition of two weeks that it took to make the move was also measured.

The results were ***significant***. Beck points out that, "according to the study, productivity shot up ***16 percent*** because of the overall combined effects of the new facility." One specific area that was measured was the impact on productivity of using environmentally responsive workstations (ERWs). ERWs allow the employees to control HVAC (temperature and air flow) and lighting at each workstation location. The HVAC source is supplied from the raised floor (which is required for access to wiring) under the workstation. The ERWs were randomly turned off during a two week

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* Beck, Paul E. (1993, January). Intelligent Design Passes IQ Test. Consulting-specifying Engineer, pp. 34-37.

period. The result was that productivity decreased 2% for those workers affected. This translates into a productivity increase of two percent directly attributable to the ERWs. This number can be considered conservative since many employees demanded that their ERW be immediately turned back on. These employees had to be eliminated from the study. It is estimated that if they were factored back into the study, the productivity increase would have been between ***five and six percent.*** Resulting savings from use of the ERWs alone using the two percent figure were $260,000. This can be considered significant based on the company's annual salary base of $13 million. ***If the five to six percent figures are used, the system would have paid for itself in less than one year.***

Intelligent Buildings — Operational Costs

In an paper presented at the IBI/IBIF Future/Build 2000 Conference held in New York City in October 1990 by the Intelligent Buildings Institute Foundation (IBIF)* Integration Task Force**, some "typical operating cost savings that 'real people' have achieved in 'information age' buildings" were presented:

- o Energy costs reduced by 15%-30%
- o Operating and security staff size reduced 25%-50%
- o Telecommunications moves, adds and changes costs reduced

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* The *Intelligent Building Institute Foundation* is the educational and scientific partner of the *Institute*, organized specifically to undertake research and educational programs beyond the scope of the *Institute* itself. See the Intelligent Buildings Institute, Intelligent Building Definition, (1987) for more information.

** IBIF Integration Task Force, Systems Integration of Modem Building Components Into "Information Age" Buildings, IBI/IBIF Future/Build 2000 conference, New York City, Oct 1990.

by 40%-70%

o Time building space is unavailable to rent or use because of renovations reduced 30%-70%

o Absenteeism reduced by 5%-10%

o Disaster recovery costs minimized

Beck's article on the West Bend building provides some important insights on how intelligent buildings can reduce ***operational costs*** that contribute significantly to the long-term savings in building life-cycle costs. Beck cites several examples of benefits of the West Bend building; namely, flexible air distribution, energy efficiency/thermal storage, and integration.

Flexible Air Distribution. The raised floor air distribution system at West Bend was required in order to use the ERWs. Since air distribution is under the floor, Variable Air Volume (VAV) boxes and the amount of ductwork required were reduced. The area under the floor is pressurized so that an ERW can be attached to the system at any point. The raised floors also include communications and electrical wiring and facilitate making changes. This flexibility factor has become more important with the continual advances that are taking place in computers and communications systems and the growing dependence on them in the modern work environment. Theodore R. York, consultant and member of the IBI, in his article Can you **afford** an **intelligent** building?*, emphasizs the role of communications and technology in the workplace and states that "modern office buildings, in effect, are evolving into computer rooms",

* York, Theodore R. Can you **afford** an **Intelligent** building? (no date)

which have traditionally been designed with raised floors for many years. Raised floors also make it easier to accommodate organizational changes. York points out that "the rate of churn (floor plan moves and changes) averages close to 33 percent per year in the United States. That represents the equivalent of an almost complete building change every three years!" York goes on to say that:

> The costs of both change and maintenance are exceptionally high in traditionally planned buildings and, in many instances, will deter and defer needed changes at the cost of organizational comfort and efficiency. In fact, many traditionally designed facilities become obsolete and have to be completely refurbished at an early age — primarily due to wiring and wiring distribution problems created by organizational change and advances in technology.

Energy Efficiency/Thermal Storage. A number of energy-efficient systems along with high-E glass and a tight well insulated building envelope, reduced the West Bend building's overall electricity costs to $0.11 per square foot in its first full year of operation. Beck compares this with "an average of $0.18 per square foot in the company's previous building. The $0.07-per-square-foot savings is particularly impressive given that the new building is all electric." A partial thermal-storage system was also installed that "cut energy costs by shifting electrical demand to off-peak hours". This combination of thermal-storage and energy-efficient systems, permitted West Bend to take advantage of utility-incentive programs and allowed them to keep the project within a $90/sq. ft. budget even though significant levels of high technology were used in the project.

Integration. The new West Bend Mutual's headquarters building consist of many different building systems and services that use "off-the-shelf" technology. However,

it is ***not*** the individual systems themselves that provide the comfort environment and energy savings ***but*** the way these systems are integrated to create a unified and centrally managed whole. As Beck puts it, "The building-automation system makes use of distributed direct digital control[2] to tie together heating, ventilating and air conditioning, security and fire-protection systems and many of their subcomponents." In this way, the systems are integrated "to produce a more comfortable and productive work environment for West Bend employees."

Open Systems Model & Protocols. An important part of ***integrating*** different systems is the set of rules or protocols by which these systems talk or communicate to each other. Data must be shared by different systems in order to achieve greater efficiency and cost savings. The Intelligent Buildings Institute Foundation (IBIF) in their report on Global Protocol Review & End-User Needs Analysis presents an overview of the ***open*** protocols issues, the results of an end-user Market Study and protocol evaluations.[3] The integration of building systems usually involves "two or more computerized building automation systems to meet user requirements[4] more effectively than would similar systems operating alone. The real advantage of integration occurs when events in one system cause a series of programmed responses to be implemented in other systems". The IBIF report cites the following example:

> If a fire detection system detects a fire, it would provide a coded global alarm message that would alert the heating, ventilation and air conditioning (HVA)C system to perform smoke containment via zone pressurization. In the same situation, the central computer can locate the fire zone and interact with the security system, switching appropriate stairwell and exit doors

from a secure mode to an access mode.

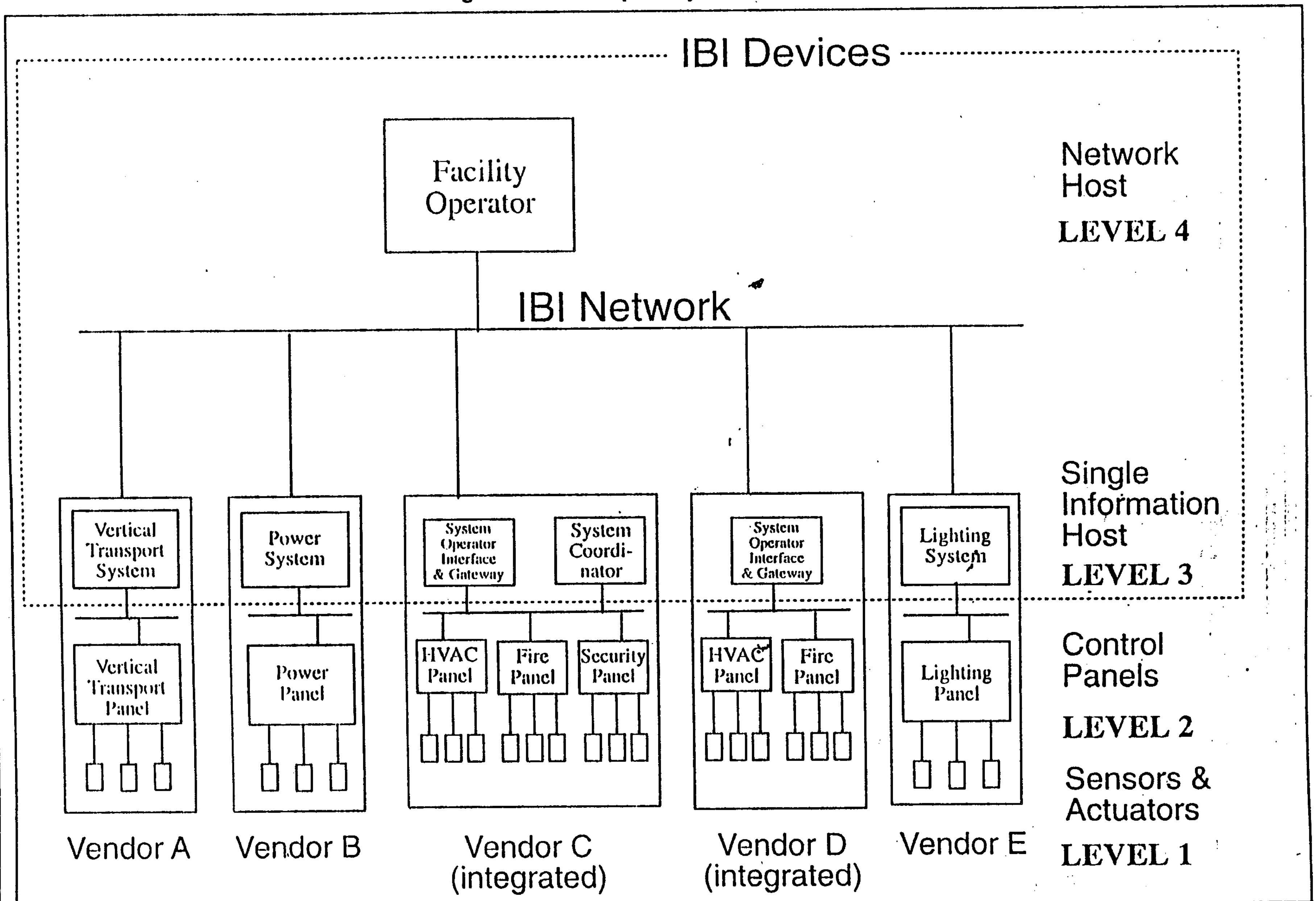
When surveyed about which systems required the most interconnectivity, end-users responded with heating, ventilation and air conditioning (HVAC), lighting control, security, fire/life/safety, power monitoring and control, and vertical transport. These systems are shown in the proposed "IBIF Open System Architecture" shown in Figure 2. Explanations of the levels follow:

o Level 1: devices such as sensors and actuators or unitary controllers

o Level 2: devices like direct digital control panels (this level is not necessary — numerous building systems contain only level 1 and 3)

o Level 3: contains the system level operator interface devices; consist of a computer that displays system-specific information and alarms

Figure 1: IBIF Open Systems Model



Note: Vertical boxes represent individual system architectures that are likely to be vendor- and site- dependent.

Source: Anil Saigal, Honeywell, Inc.

IBIF

Figure 2

o Level 4: devices include personal computers or minicomputers which monitor performance, provide a consistent operator interface to the entire set of building systems, and perform coordinated control across multiple building systems

Level 4 is the top level of the open system architecture and is where operations are performed that can be considered in the domain of the intelligent building. At this level, global information allows systems to interact intelligently. In the model, the level 3 and 4 boundary contains the global information used to perform integrated system functions. The IBIF report lists numerous examples of value-added services which result from integrated systems functions.[5] The value-added functions at the top level of the open systems architecture provide the real increases in efficiency of building operations and reductions in life cycle-costs.

Proprietary vs ISO/OSI Model Protocols. The communications industry has been supporting the development of standard protocols for a number of years in order to facilitate the integration of different vendor products. A key objective of end users has been ***not*** to become completely dependent on a single vendor's products. In order for vendors to develop products that easily integrate with other vendor's products, the International Organization for Standardization (ISO) developed an Open Systems Interconnection (OSI) model for ***communications*** protocols.[*] The ISO/OSI seven layer model[6] provides a standard that protocol developers can build to that allows their

[*] Caloz, Jack W., & Geissler, R. G., (April 1994), OPEN PROTOCOLS: More Promise than Payoff for Commercial Building Operators, Washington DC.

products to be integrated with many other products developed to the same standard.

Compared to the communications industry, the buildings control segment of the economy can be considered to be lethargic. As Coloz and Geissler point out in their paper, "the building controls industry is too small to expect revolutionary technological advancement"...and it "is slow to change. Lip service is paid to using new technologies to save money and operate more efficiently..." However, there are several ***standard*** building control protocols that are currently in development. One that is gaining in acceptance is BACnet (Building Automation and Control Network) protocol developed by ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers). It was developed over a period of seven years and a revised draft is under review with final comments due 16 May 94.[*] According to Coloz and Geissler, "BACnet is an object-oriented software program which incorporates Layers 1, 2, 3, and 7 of the ISO/OSI model. It is designed to operate over Ethernet, ARCnet, or a specially-defined RS-485 asynchronous bus using twisted-pair at speeds up to ***78 thousand bits per second.***" (Note: Compare this to factory automation protocols which require ***response times in the millisecond range***; the FIP - factory instrumentation protocol - developed in France operates at speeds up to 5 million bits per second.) They go on to say, "the National Institute of Standards and Technology (NIST, the successor of the National Bureau of Standards) is the focal point for the ***BACnet Interoperability Testing Consortium.*** The consortium[7] was established under a federal law allowing competitors to cooperate in product development when it

[*] Ibid.

benefits American industry in toto."

Two "chip-based" protocols that are gaining momentum are Echelon from Echelon Corporation, Palo Alto, California, and ISP from InterOperable Systems Project Foundation, Austin, Texas -"a not-for-profit organization established by major vendors frustrated with the lack of progress....*" Echelon is a protocol that "is implemented on its (VLSI) chip and contains all seven layers of the ISO/OSI model and can communicate at speeds ranging from 5000 bits per second to 1.25 million bits per second.** ISP is a (Toshiba and Yokogawa) microchip designed for the factory floor but being modified for use in the building controls industry.

Coloz and Geissler conclude that "standard protocols will be adopted, despite the vendors because the end users want them." If the major building control manufacturers do not get out in front and actively promote open systems, they may be left behind by much smaller but very innovative firms.

Intelligent Buildings – Initial Costs

In the not too distant past, many owners considered the concept of intelligent buildings as one that was loaded with technology and very expensive to implement. It was an alternative that owners generally did not want to spend extra money for. However, in her article Smart Buildings Gutsy Changes***, Nadine M. Post points out

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* Ibid.

** Ibid.

*** Post, Nadine M.. (1993, May 17). Smart buildings make good ene. Engineering News-Record. pp. 24-28.

that first generation smart buildings were typically run by expensive main-frame computers and the field was vendor driven. She states that the difference between the smart building of today and five or ten years ago is the difference that distributed processing and digital controls have made in general. This new technology is "tried and true, and it costs less." She goes on to say that the building systems of today are run by microprocessors that are networked and remoted to host microcomputers.

Theodore R. York, consultant and member of the IBI, in his article Can you **afford** an **intelligent** building? comments that an intelligent building can be built with much less initial cost than is commonly perceived and that the initial cost of an intelligent building can come close to equating to the initial cost of a traditional building." He continues with "The big pay-off in an intelligent building is in its sharply reduced ***life-cycle costs*** and its insulation from obsolescence." Anne Garvin in her article in The Construction Specific, The Intelligent Workplace*, discusses the views of Professor Volker Hartkopf, Carnegie Mellon University Department of Architecture, on "placing an inappropriate emphasis on first costs for a building project," and "describes this emphasis as a major roadblock to creating workspaces that increase user satisfaction and enhance productivity." She quotes him as saying 'First costs reflect only 2 percent of the overall cost of operating a building. Most of the cost associated with operating a building—some 90 percent of it—goes to salaries earned by the employees in that building.' She goes on to say that an intelligent building's first costs may be higher than traditional market standards, however, a good design can result in

* Garvin, Anne. (1993, January). The Intelligent Workplace. The Construction Specifier. pp. 36-43.

savings over time.

Garvin argues that initial costs can be paid back by calculating savings from operation expenses:

> A $20 million facility could easily cost one million dollars a year in energy and maintenance costs. If you can improve the productivity, decrease the energy consumption, streamline maintenance, and increase the long-term viability of the structure, the higher first costs may be recovered in only two or three years. And it's not always necessary to spend more money if you start with a better design.

In addition to the operational cost savings cited previously in this paper, the IBIF Integration Task Force paper also examined ***initial building costs*** and examined ***four alternatives*** each with a different ***integration concept.**** Using **ALT 1** as a base, the alternatives and their cost ratio follow:

ALT 1 - **TRADITIONAL**...an attempt to minimize initial capital investment (even at the risk of increasing life-cycle costs) - ***Cost ratio: 100.0%***

ALT 2 - Cellular deck for wire management plus selected upgrades of building automation system (BAS), fire, and security systems - ***Cost ratio: 102.5%***

ALT 3 - Raised floor (6") for wire management, plus integrated BAS, fire, and security systems - ***Cost ratio: 101.0%***

ALT 4 - Raised access floor (14") for wire management and HVAC

* IBIF Integration Task Force, Systems Integration of Modern Building Components Into "Information Age" Buildings, IBI/IBIF Future/Build 2000 conference, New York City, Oct 1990.

distribution plus integrated BAS, fire, and security systems - ***Cost ratio: 104.5%***

When these modest increases in initial building costs are compared to the typical operating cost savings that real people have achieved in information age buildings*, the result is ***significant*** savings over the life-cycle.

Participatory/Interactive Design

Today's building systems are becoming increasingly automated and more complex. This is especially true of the computer and telecommunication systems that are being used daily in most large office buildings doing global business. New or renovated buildings are requiring the integration of many different disciplines early in the design process. It should be noted that architects tend to concentrate on the visual rather than the performance aspect of a building and that the architectural community is only recently starting to embrace the intelligent building concept.

Post, in her article, Smart buildings make good sense**, states that in order to accommodate today's complex building systems, many intelligent building experts are "pushing a new approach called ***participatory design.*** Instead of an architect designing the building and then calling in specialists, the specialists, including those for telecommunications, meet fact-to-face before a building is designed and brainstorm with the architect, engineers, construction manager, owner and end users." In order for this approach to work, all participants must be involved in the very early stages of

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* See "Intelligent Buildings - Operational Costs" section of this paper.

** Post, Nadine M.. (1993, May 17). Smart buildings make good ene. Engineering News-Record. pp. 24-28.

design.

Anne Garvin in her article, The Intelligent Workplace[*], also discusses this approach but calls it interactive design (based on Professor Volker Hartkopf concepts at Carnegie Mellon). She states that Hartkopf says achieving a better design "hinges on ***three principles***: 1) an ***emphasis*** on a few key performance qualities; 2) ***integration*** of building systems to achieve that performance; and 3) an ***interactive team approach*** to design to ensure successful integration of the building systems." The interactive design team members include the architect, engineers, and consultants who work together throughout the entire project. To get a better understanding of the new responsibilities of each of the players, a matrix was developed that shows the "traditional" vs "necessary" accountabilities for building performance (Figure 3)[**]. As seen in the figure, the design team approach requires team members to address a number of performance issues during the design, and not just specific building subsystems they have been traditionally responsible for.

Now that we understand some of the principles associated with the Intelligent Building concept, let's examine how they may impact the Pentagon Renovation.

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[*] Garvin, Anne. (1993, January). The Intelligent Workplace. The Construction Specifier. pp. 36-43.

[**] Ibid.

Traditional Accountabilities for Building Performance

	SPATIAL QUALITY	THERMAL QUALITY	AIR QUALITY	ACOUSTIC QUALITY	VISUAL QUALITY	BLDG INTEGRITY
ARCHITECT	●●			●	●	●●
MECHANICAL ENGINEER		●●	●●			
ELECTRICAL ENGINEER	●●				●	
LIGHTING EXPERT	●				●●	
ACOUSTICAL EXPERT						
STRUCTURAL ENGINEER	●					●●
INTERIOR DESIGNER	●●			●	●	●●
ENERGY CONSULTANT		●●	●		●●	

Necessary Accountabilities for Building Performance

	SPATIAL QUALITY	THERMAL QUALITY	AIR QUALITY	ACOUSTIC QUALITY	VISUAL QUALITY	BLDG INTEGRITY
ARCHITECT	●●	●●	●●	●●	●●	●●
MECHANICAL ENGINEER	●●	●●	●●	●	●	●●
ELECTRICAL ENGINEER	●●				●●	●
LIGHTING EXPERT	●●	●	●	●	●●	●
ACOUSTICAL EXPERT	●●			●●		●
STRUCTURAL ENGINEER	●●	●	●	●		●
INTERIOR DESIGNER	●●	●●	●●	●●	●●	●●
ENERGY CONSULTANT	●	●●	●●		●●	●●

●● Primary Responsibility/Accountability Taken for Building Performance
● Secondary Responsibility/Accountability

Figure 3. **In the traditional approach to building design, professionals are accountable for specific subsystems, whereas in a team approach to design, the team members bring their particular expertise to bear on performance issues in the design.**

THE PENTAGON RENOVATION

The Intelligent Building concept emphasizes the integration and synergism of the building structure with building systems, services, and management. The idea is to construct a building that meets the needs of the occupants, reduces life-cycle costs, and improves overall productivity. One of the functional areas that will require significant change during the renovation is the new Information Management and Telecommunications (IM&T) architecture and associated "centrally" managed organization that must be created to operate and maintain it.

Information Management and Telecommunications (IM&T)

IM&T includes all computer or communications equipment and services that provide telecommunications connectivity for the National Capital Region, OSD, Joint Staff, National Military Command Center, Service Operations center, Intelligence Center, military Services and DOD Agencies within the Pentagon.

The scope of the IM&T effort includes development of an objective (Red-secure/Black-unsecure) backbone architecture, collocation and consolidation of communications technical controls, message centers, business ADP, Black and Red communications switches, and command and control ADP, and the transition planning and associated engineering integration required for the movement of military Service and Agency command centers.

New IM&T Technology and Backbone Architecture. The current IM&T

architecture is costly, inefficient, and inflexible. Over the years each Service/Agency has implemented its own separate video, data, and voice networks throughout the Pentagon. There has been no central management organization to oversee and provide configuration management of the IM&T infrastructure for the building. Consequently, there have been duplication and interoperability problems between and within the Services/Agencies. As discussed above under "Intelligent Building Characteristics", there are a number of advantages to ***centralized*** communications within a single facility. It is important that the Pentagon Renovation capitalize on these advantages and not continue the current separate and duplicative services that currently exist.

Technology available in the 1990s will allow for the merging and integration of what were once separate and distinct video, data, and voice networks into a single (bandwidth-on-demand) physical network. The use of Synchronous Optical Network (SONET) for backbone transmission and Asynchronous Transfer Mode (ATM) cell switching will accommodate all Pentagon users and provide standard services on a single, centrally managed Broadband Integrated Services Digital Network (BISDN).

IM&T Management and Organizational Impacts. Integration or merging of video, data, and voice network services into a single infrastructure for the entire Pentagon will require the ***unification*** of existing management and organizational structures. A new organization must be created to manage IM&T functions centrally across the Pentagon facility. Care must be taken ***not*** to fragment or weaken this new organization by separating facility IM&T functions and allocating them to the various

Services and Agencies within the Pentagon.

It is important that we posture ourselves organizationally before the Renovation process begins so that IM&T implementation and follow-on operations and maintenance are facilitated. This is not unlike the new development of a weapon system where the Readiness Command is "on-board" with the Development Command early in the development process.

Renovated Pentagon - Evolving to a Single System.

The Renovated Pentagon should be viewed as a single system with distinct subsystems that encompass the user needs and objectives. An important point that must be emphasized here is the need for integrated management of services and systems throughout the building into a unified whole.

Technological advances have provided the capability to monitor most processes automatically within the subsystems described above. This includes integrated management control systems for lighting, HVAC, fire and life safety, security access, local area networks and telecommunications. However, there are no manufacturers that currently integrate all three of these subsystems into a ***single integrated management subsystem.*** *

The IBIF Open System Architecture (Figure 2), although an important goal to support, will not be a reality in time for an open building systems implementation in the Pentagon Renovation. A MITRE Corporation report on Pentagon Automated Building Control Systems Integration concluded that "the use of proprietary technology by each

* Systems Engineering Directorate, U.S. Army Information Systems Engineering Command. (January 19, 1993). Functional Description Intelligent Administrative Building. pp.54.

vendor's system entails a degree of system integration that is both complex and difficult " and that "a ***single vendor approach*** should be considered to provide building control systems for the Pentagon renovation." The report also suggested that if, contractually, a single vendor approach was not feasible, consideration should be given to physically grouping the "individual building control systems, such that all are collocated, but not integrated; allowing for possible future integration as building control systems technology matures towards standards-based applications." Although integration of all building subsystems will not be possible in the early stages of the renovation, the standards and vendor acceptance of an open systems approach may well be available in the later stages of the renovation. It would make sense to posture ourselves physically from a building structure perspective, and organizationally (central management) so that when the technology is available it will be relatively easy to implement.

Facility Command and Control Center Concept. Automated building control systems could be monitored and controlled by separate organizations or consolidated into a single organization running a single central command and control center for the building. Although each of the subsystems functionally controls different processes, the associated sensors and electro-optical control mechanisms could be monitored by a single set of systems management specialists. Sensor data from the various subsystems would terminate in the command and control center. This center would be the central "command and control"(C2) point for ***all*** the subsystems within the building. Operations and maintenance monitoring functions could be centralized in this

C2 facility for the entire building. Automated problem reporting, billing, performance and security network management for all building systems could be centralized in this facility. Centralized management and use of automated facility controls should result in cost savings due to reductions in operating and maintenance staffs. However, personnel will require new skills, capabilities, and responsibilities to implement and operate in a new centrally located network management environment.

Participatory/Interactive Design

The Participatory or interactive design concept is fundamental to the successful implementation of the Pentagon renovation. The traditional mind-set associated with the roles of the architect and building system engineers must be changed to reflect secondary as well as primary responsibilities in working performance issues during the design phase. Active involvement with the occupants and a thorough understanding of their needs is essential to successful implementation.

The management process of how members of the team interact, which includes the rules and procedures for conflict resolution between organizations, cannot be over-emphasized. Problems with this process can result in program delays, wasted time and effort, and above all, implementation of a project that does not meet the occupants' needs and unnecessarily adds to building life-cycle costs. Consensus building should be practiced with particular emphasis on involving the building occupants in the decision making process. In the Pentagon, there are three different "types" of occupants that must be intimately involved in the early design process and must be considered key members of the project design team: 1) functional end-users

the building will ultimately serve, 2) building management (operational and maintenance) personnel who are responsible for planning and day-to-day operations, and 3) technical support organizations that work directly for the occupants – IM&T and command and control support organizations are good examples. Procedures that allow quick access to upper management of the military Services and DOD Agencies within the Pentagon are also essential to successful project implementation.

Environmentally Responsive Workstations (ERW).

The most significant problem that occupants have with the Pentagon is the poor quality of the air and the (often severe) temperature swings throughout the building*. As discussed earlier, ERWs allow the employees to control HVAC (temperature and air flow) and lighting at each workstation location. However, implementation requires the used of raised floors. Current plans for the Pentagon Basement/Mezzine call for raised floor (12 - 18 inches) since a large part of this area will be used for the National Military Command Center, Service/Agency command centers, and large communications and ADP centers. Based on lessons learned (e.g., West Bend productivity gains) ERWs should be installed in the Basement and Mezzanine. However, discussions with Pentagon Renovation project personnel indicate that raised floors are not planned for the rest of the building. Reasons cited are 1) cost and 2) ceilings too low (7.5-8 feet) with raised floor implementation. No formal studies have been conducted to examine the raised floor alternative. Given the potential payback over the life of the building, serious consideration should be given to conducting a

* This is a given. The author's personnel experience of working within the building for over five years and discussing air temperature and quality with many of the occupants is verification of the problem.

formal study on how raised floors and ERWs could be implemented in the above-ground portion of the renovation.

Building Life-Cycle Costs vs Initial Cost.

The logical argument goes: if significant savings can be obtained over the long run with a larger investment up-front, then do it. U.S. business has had difficulty with this concept over the past two decades. Short-run profits and positive balance sheets are what pleased the stockholders; consequently, long-term business viability in a global market played a back seat. Short-term advantages can often translate into long-term problems -- in this case, a loss of global market share.

The government has its own short term pressures. Recent cuts in the Department of Defense budget have put severe pressures on minimizing short-term initial costs even when there are clearly significant long-term operational and maintenance cost advantages. One often has to pick an initial cost figure that is solely based on what's "acceptable" to Congress and not what benefits the taxpayer in the long term. Although these circumstances are often what we must live with, government officials have an obligation to conduct life-cycle vs initial cost analysis so that those in leadership positions within DOD and Congress can make the appropriate decisions based on factual data.

The IBIF Integration Task Force, as discussed earlier, showed that Intelligent Building initial costs were within 4.5% of "traditional" building costs. In addition, technology and competition are driving Intelligent Building costs down. Senior leadership within the Pentagon Renovation Program should insist that an in-depth cost

analysis be performed on Intelligent Building life-cycle costs vs traditional building initial cost. The analysis should be based on what all team members consider to be essential building performance criteria. Who knows – senior leadership within DOD and Congress might even support a little more dollars up-front when backed by accurate and factual analysis. The taxpayer deserves at least this much consideration.

CONCLUSIONS/RECOMMENDATIONS

The Intelligent Building concept is one that, if carefully managed, will reap long-term life cycle cost savings and provide business and government productivity gains which can assist in maintaining a competitive edge in today's global economy. The Pentagon Renovation is one of the largest projects of its kind in the world. It provides an opportunity to provide long-term benifits for the 25,000 plus employees that work there as well as saving the taxpayer dollars by implementing integrated building systems that will reduce building life-cyle costs.

CONCLUSIONS.

o Technology advances have reduced the costs of automating and integrating building systems. Intelligent buildings have significantly lower life-cycle costs than "traditional" buildings with only slightly higher initial costs.

o Operational and productivity savings over the life cycle can be significant in properly designed and managed Intelligent Buildings.

o The participatory/interactive design concept should be used during the renovation to manage the design process. Early involvement by the architect, engineers, construction manager, owner and occupants in a concensus-building atmosphere is essential. Pentagon Renovation leadership must be committed to the long-term by emphasizing the importance of building life-cycle cost.

o Building performance criteria and life-cycle cost alternatives for the renovation must be ***formally*** analyzed early in the design phase.

o The Pentagon physical structure should be thought of as a significant tool in the accomplishment of user/occupant tasks rather than just a structure to house personnel and equipment.

o The environmentally responsive workstation (ERW) along with the necessary raised floor should be seriously considered for the above ground portion of Pentagon Renovation. Life-cycle cost savings should be factored into the decision process.

o Central management of all building systems, including information management and telecommunications (IM&T), is essential in order to facilitate operations and maintenance and realize life-cycle cost savings.

o Open/standard buidling control protocols will be developed in the near future which will allow integration of multivendor products. In the near term, renovation managers should plan for easy transition to the new multivendor era when it arrives.

o A facility command and control center concept with centralized management and automated controls for all building systems (including IM&T) would provide efficient and cost effective building operations and maintenance at a much reduced staff level.

o A long-term objective of both IM&T and building management personnel is an automated Pentagon in a "lights-out" operation.

RECOMMENDATIONS.

o Building performance requirements should be developed and life-cycle cost analyses conducted to determine feasibility of implementation. If analysis shows significant life-cycle savings but initial funding is not available, the case should be presented to DOD and Congressional leadership.

o Pentagon Renovation leadership should take action to implement the participatory/interactive design concept with emphasis on developing a team (with significant user/occupant input) that is committed to achieving the goal of creating a new "intelligent" Pentagon that will minimize building life-cycle costs.

o A formal study should be initiated on the feasibility and life-cycle cost effectiveness of using environmentally responsive workstations (ERWs) throughout the Pentagon.

o A central management organization should be established to manage all Information Management and Telecommunications (IM&T) within the Pentagon. A separate facility command and control center should be established that would house both IM&T and building automation systems. Organizational and procedural relationships between IM&T and building management personnel would have to be developed. "Lights-out" operation should be a long-term objective.

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1 The following information was taken from an abridged version of a paper presented at the IBI/IBIF Future/Build 2000 Conference held in New York City in October 1990.

"The Intelligent Buildings Institute is the only international professional trade association in the U.S. serving all sectors of the intelligent building community. The Institute was incorporated August 12, 1986, as a not-for-profit entity under Section 501(c)(6) of the Rules of the Internal Revenue Service to serve the needs of manufacturers of products and systems, design professionals (including architects, engineers, and consultants), contractors and distributors, building owners and operators, telecommunication and electric power utilities, research institutions, and various national and international trade associations and technical societies."

2 Excerpts from a paper, OPEN PROTOCOLS: More Promise than Payoff for Commercial building Operators, Jack W. Caloz, PE, and R. G Geissler provide some comments on **direct digital control (DDC)**:

> "DDC technology (direct digital control) offers the building operator immensely greater opportunities to monitor, in real time, what is happening to the diverse systems throughout the building. Further it provides the ability to share information among complementary systems (energy management, fire/life/safety, lighting, et al.) increasing their interoperability. Once the data flow is established, it's a short step to storing, sorting and manipulating data to create a CAFM (computer aided facility management) package."

3. It is important to understand protocols functions as well as the differences between different protocol definitions. Excerpts from a paper, "OPEN PROTOCOLS: More Promise than Payoff for Commercial Building Operators", Jack W. Caloz, PE, and R. G Geissler provide some insights:

PROTOCOL: A formal set of conventions governing the format and relative timing of message exchange between two communicating systems. In layman's terms, it is the software language that provides communications between devices and systems, including the ability to monitor and command. Almost all protocols currently being considered by the commercial building industry are formed on the seven-layer ISO/OSI model.

FIELD BUS: An all-digital, two-way communications system used for communication among field instruments and control room systems. Such instruments can include transmitters, control valves...motors, PLCs, etc. A field bus is, in the minds of many control engineers, a "mini-protocol" software language which addresses the first three layers of the ISO/OSI model.

STANDARD: A standard, as in "standard Protocol" is a term with legal and procedural meaning. A standard is developed and published by an accredited standards organization within the context of federal anti-trust laws. Participation is voluntary; there is a published procedure for adopting and periodic revision; there are rules for appeals and other constraints to protect individual companies. A standard guarantees greater stability in the market, but the process to create and adopt a standard can be painfully slow. An example of a standard in process is BACnet, being developed by ASHRAE.

OPEN: An open protocol is just that -- open to whomever wishes to use it, open to change, open to being withdrawn. Participation is voluntary. Most often it is a protocol developed by a vendor and made available at either a nominal fee or at no cost. An example of an open protocol is the one which Snyder General makes available to component manufacturers or end-users who wish to integrate with their product line.

PROGRAMMING/ COMMISSIONING: When a control system is installed in a building on campus, or a wing is added to a building, the system must be programmed to function within that environment. Temperature parameters are set, air flow regulated and other balancing done. A commissioning sequence is established to bring the area and system on line. None of the standard or open protocols currently being considered address that base-level issue of getting the new space or building up and running.

4. The IBIF report defines end-users as being comprised of one of the following three groups: government agencies (including institutions and educational organizations), designers (architectural and architectural/engineering consulting firms), an owner's facility managers, building owners, and development companies).

5. For examples of value-added services which result from integrated systems functions see pages 9-11 of IBIF report.

6 The Coloz and Geissler paper provides the following description of the ISO/OSI seven layer model:

LAYER 7 - APPLICATION	Provides the interface between the network and computer applications, such as electronic messaging or file transfer.
LAYER 6 - PRESENTATION	Provides the converting function, translating data into a common format which can be understood by both sender and receiver.
LAYER 5 - SESSION	Provides synchronized communication session between application processors during data transmission; opens/closes dialogue sessions.
LAYER 4 - TRANSPORT	Ensures data flowing between systems is transported intact to proper destination and maintains integrity of data transmissions.
LAYER 3 - NETWORK	Determines the route data will take and sends data over various links to its destination within the system.
LAYER 2 - DATA LINK	Packages data sent from the physical layer so that they travel over the network.
LAYER 1 - PHYSICAL	Contains the rules for use of various physical media, such as UTP, STP, fiber optic, to transmit data bits.

7 ***BACnet Interoperability Testing Consortium***:

American Auto-Matric, Export, Pennsylvania

Andover Control Corporation, Andover, Massachusetts

Delta Controls Incorporated, Surrey, B.C., Canada

Johnson Controls Incorporated, Milwaukee, Wisconsin

Landis & GYR Powers Incorporated, Buffalo Grove, Illinois

PolarSoft (software firm for sensors)

Siebe Environmental Controls, (combination of the Robertshaw and Barber-Colman companies under an English conglomerate), Loves Park, Illinois

Snyder General Corporation, Minneapolis, Minnesota

Staefa control System Incorporated, San Diego, California

The Trane company Incorporated, La Crosse, Wisconsin